

Alternative Conceptual Models of Hanford Site Hydrogeology

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Goal and Approach

- ▶ Estimate uncertainty in flow and transport at Hanford Site due to uncertainty in hydrogeology
 - Focus on unconfined aquifer
- ▶ Develop alternative conceptual models for two major elements of hydrogeology
 - Distribution of mud units in Ringold Formation
 - Zonation of Hanford formation aquifer
- ▶ Geostatistical approach
 - Generate suites of realizations using stochastic simulation
 - Rank the simulations using fast ranking algorithm
 - Run forward flow and transport code on large number of simulations to check the ranking
 - Perform inverse calibration on limited number of simulations
 - Strategy driven by current available computing power
 - Expected to change as computational power increases

Hanford Site Stratigraphy

Hanford fm (Unit 1) →

1: Hanford and
Pre-Missoula Gravels

2: Early Palouse Soil

3: Plio-Pleistocene

4: Upper Fines

5: Upper Coarse

6: Middle Fines

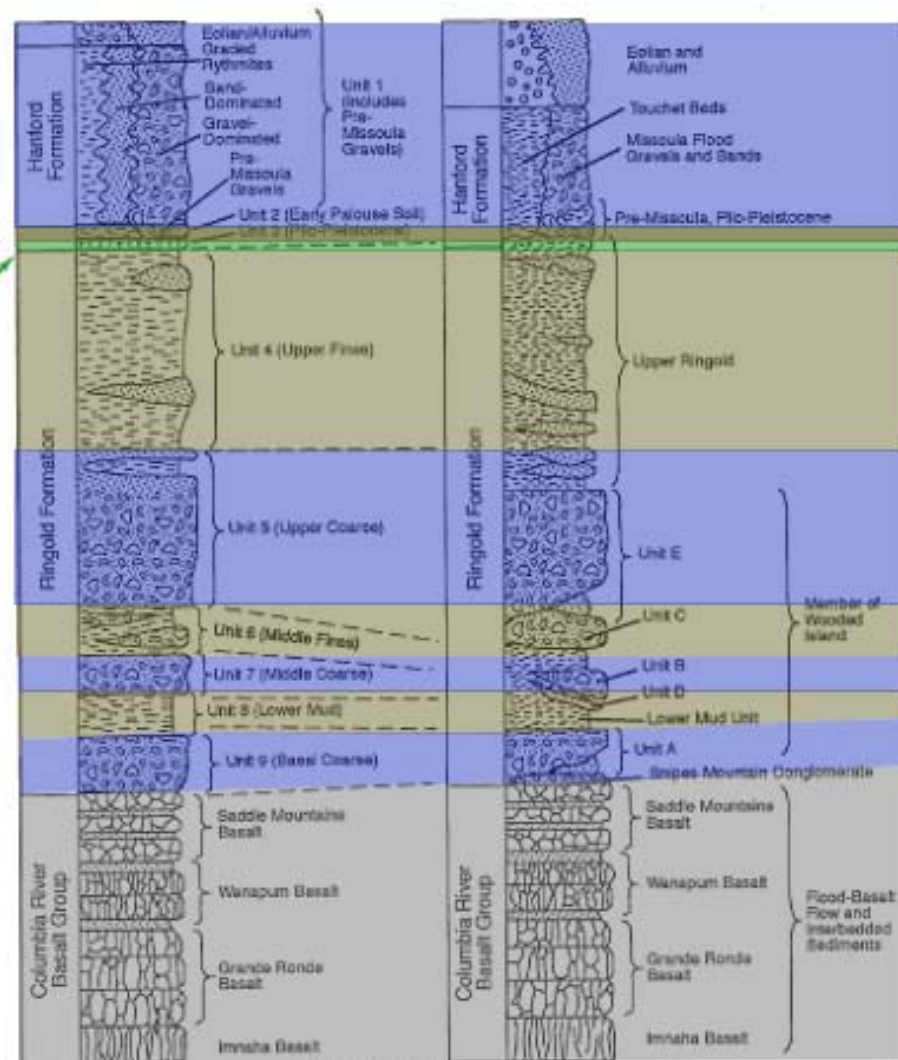
7: Middle Coarse

8: Lower Mud

9: Basal Coarse

10: Flood Basalts
and Interbedded
Sediments

Ringold Fm mud units →



From PNL-8971

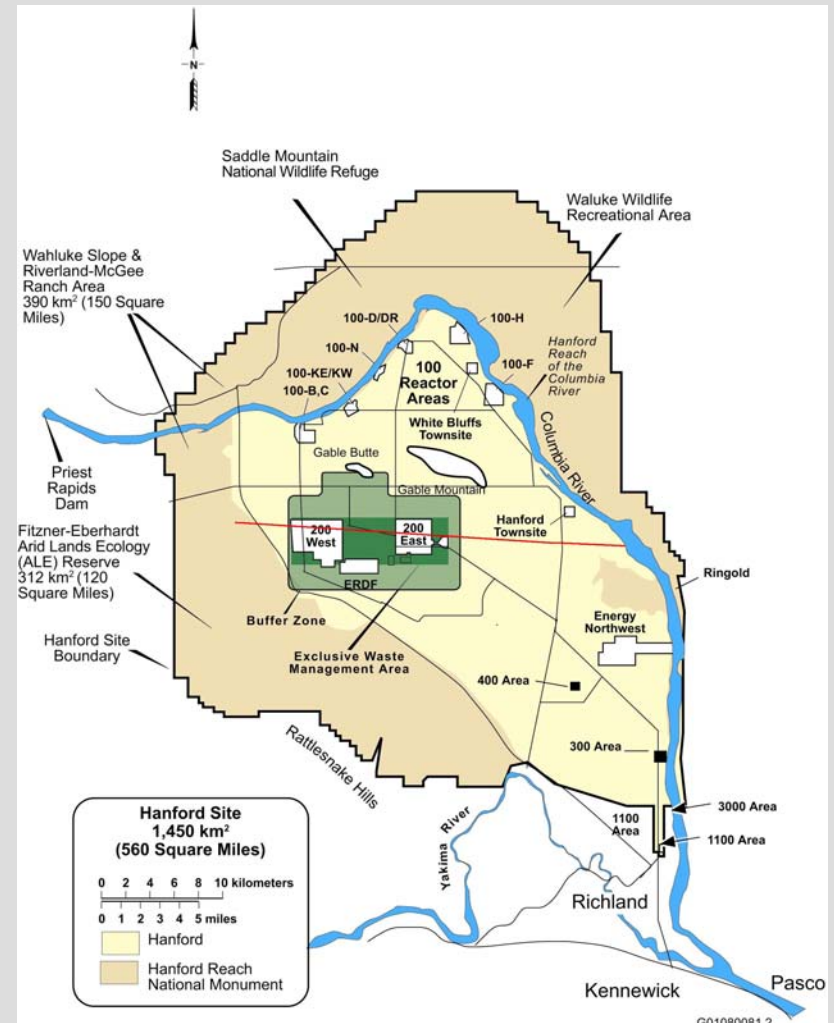
Not to Scale

After BHI-00184

Ringold Formation Mud Unit Distribution

- ▶ Hanford Site ~1500 km²
- ▶ 405 monitoring wells;
- ▶ 10 hydrogeologic units;
- ▶ Units have patchy distribution.

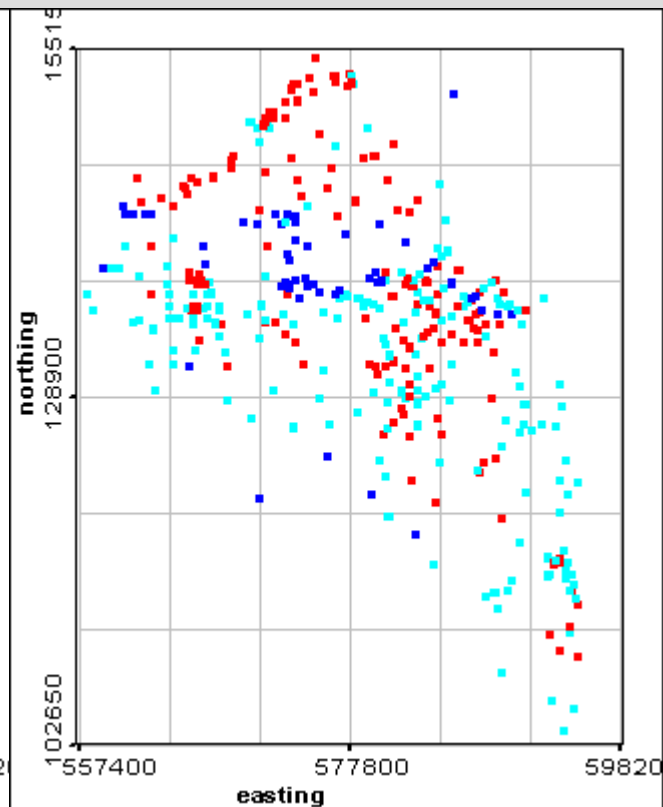
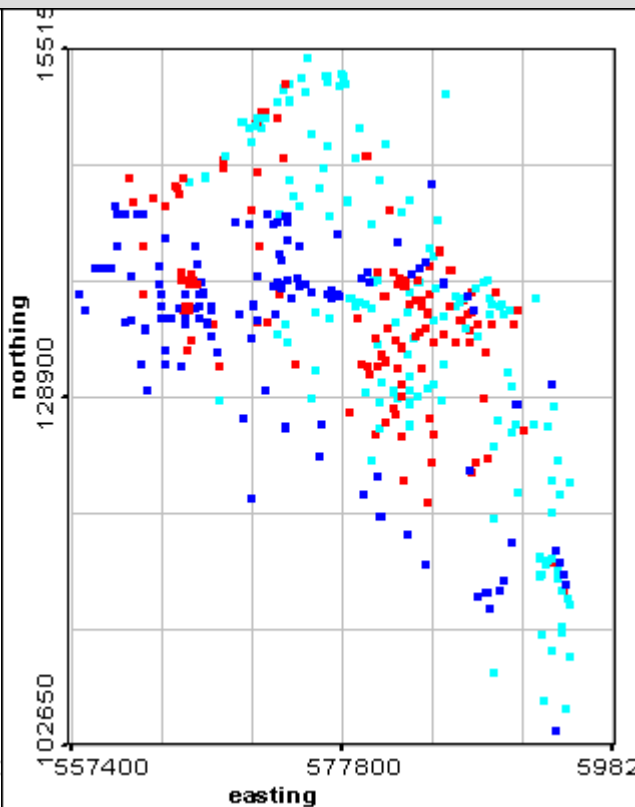
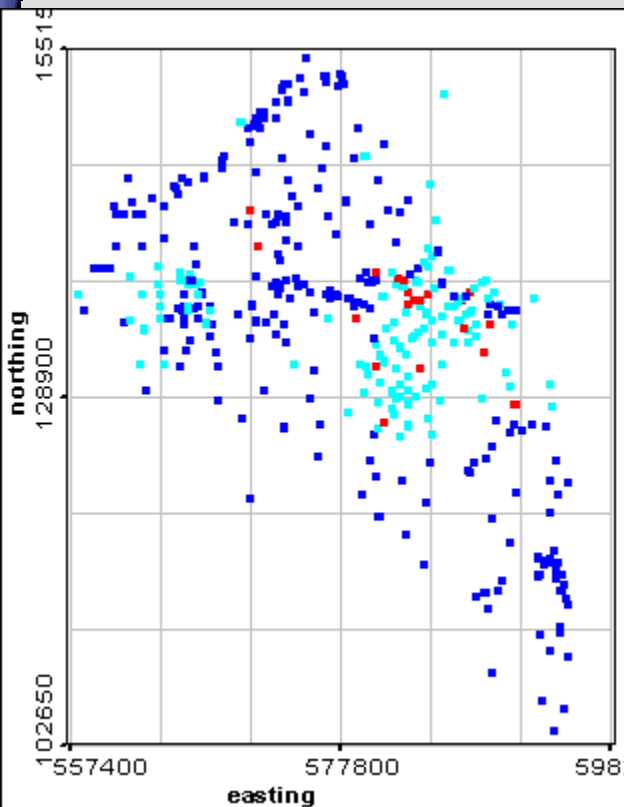
Study was performed for
3 low-permeability mud units,
because they control the vertical
groundwater movement



Raw data on presence/absence of 3 mud units

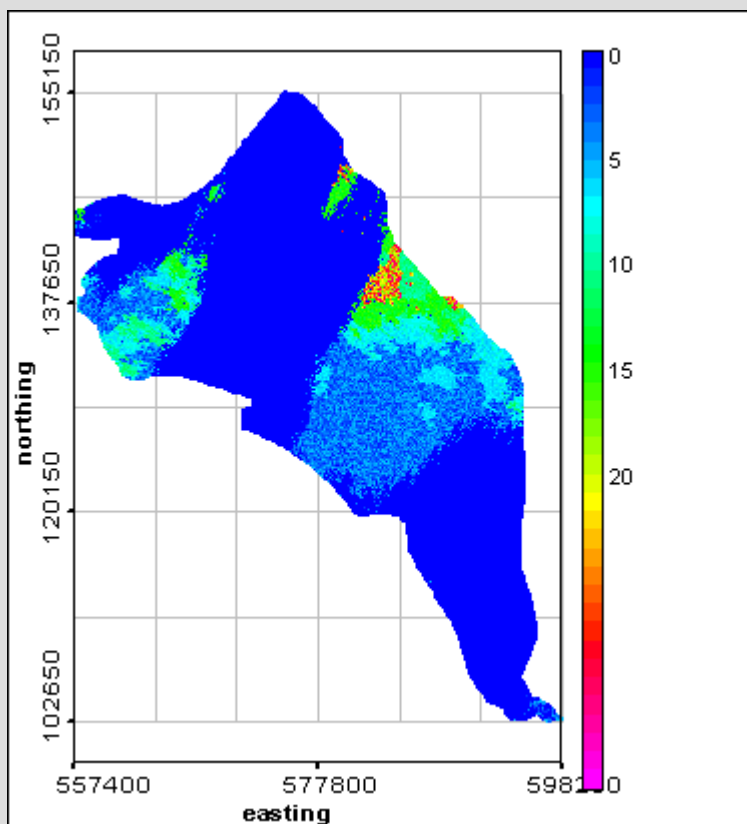
Legend

- Unit present
- Unit absent
- Uncertain well



Unit4 Geostatistical Modeling

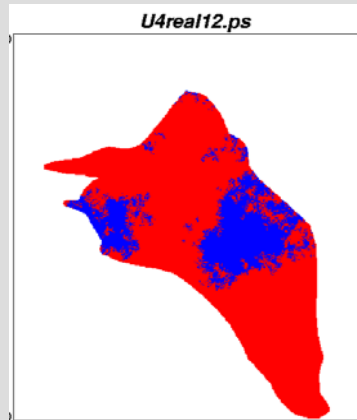
- ▶ Probabilistic model to estimate presence (threshold 0.5);
 - Using Indicator Kriging
- ▶ Sequential indicator simulation to estimate thickness for areas where Unit 4 is present



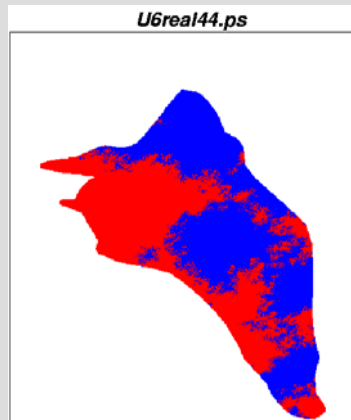
Ranking of Mud Unit Realizations

- ▶ Pseudo 3D models built by taking 2D realizations from each of the three mud units and superposing them by insertion of a sand layer in between each mud layer
 - 132,651 pseudo 3D models constructed
 - One for each combination of mud unit realizations
 - Only a single connected sand body for each 3D model
- ▶ The goodness of each 3D model is evaluated by
 - Size of the sand body: the more sand the better
 - Tortuosity of the sand body: ratio of surface area to volume, the less the better
- ▶ Ranking
 - Two ranks, one for each of the criteria
 - Final rank is the average of the two ranks
- ▶ Computation
 - Calculation of geometry of bodies and ranking of realizations performed using software adapted from Deutsch (Computers & Geosciences, v.24, no.1, pp. 69-76 1998)

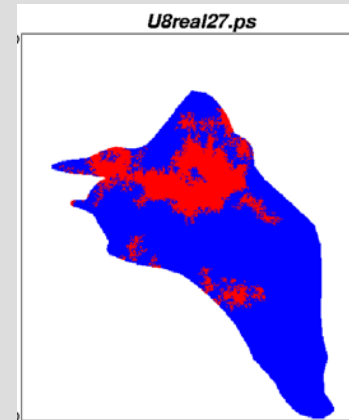
Results of Ranking Mud Unit Realizations



Unit 4

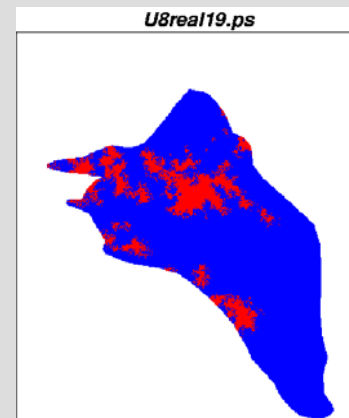
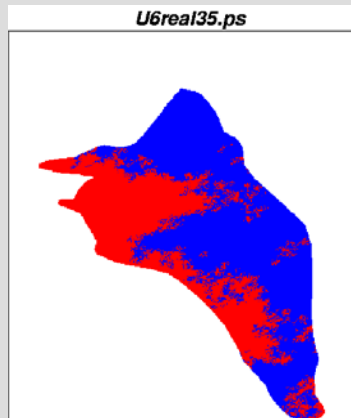
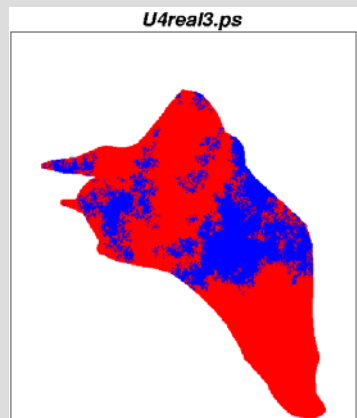


Unit 6



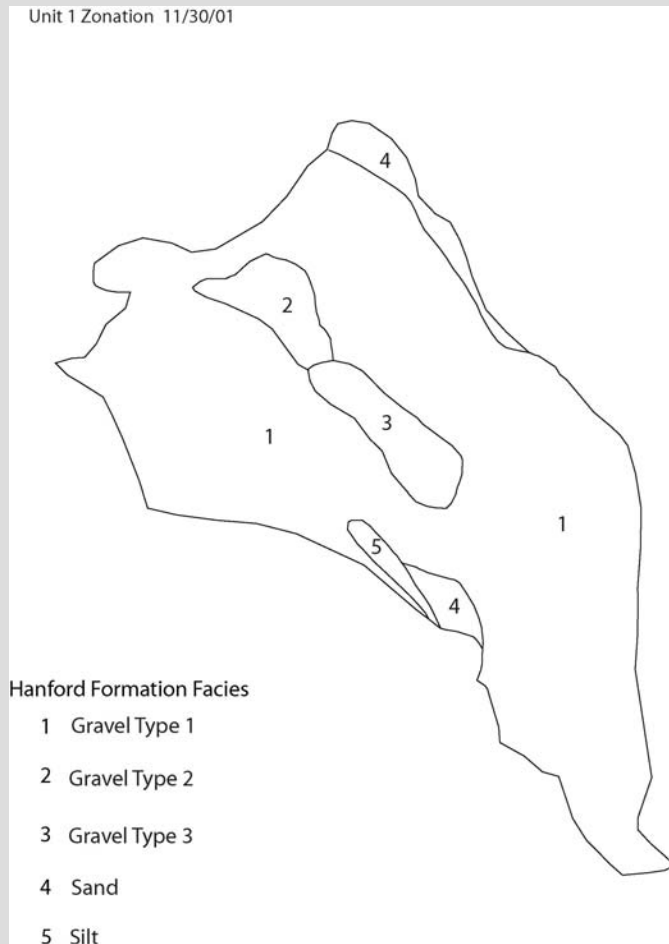
Unit 8

Most Conductive
Set of Realizations

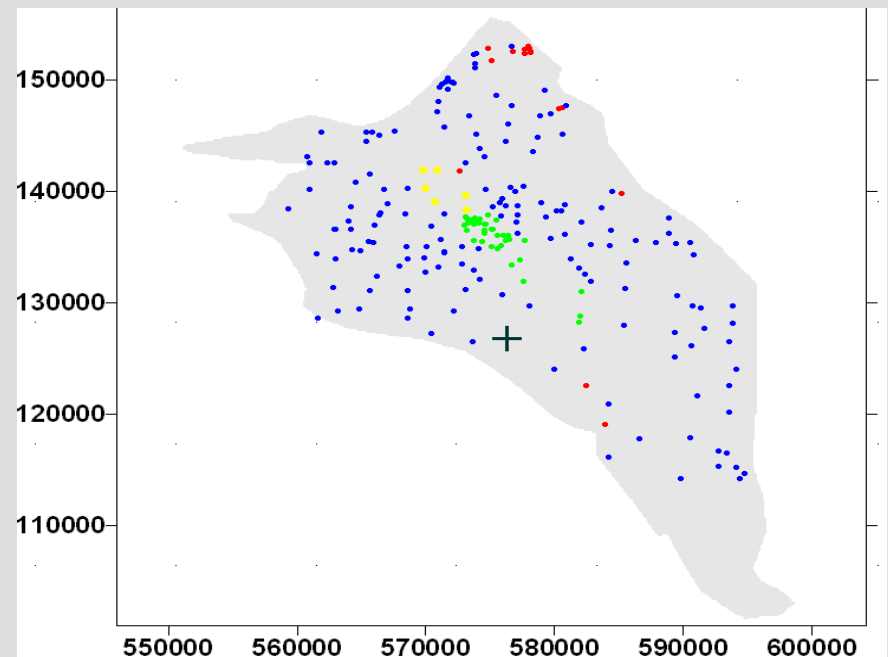


Least Conductive

Unit 1 Zonation



Base Case Model



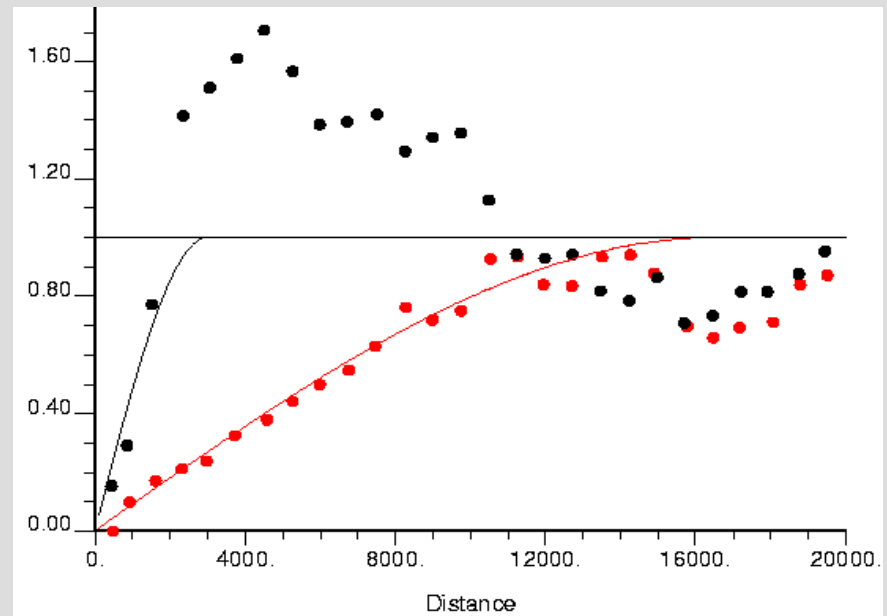
Data Distribution

Global Proportions of U1 Zones

		Proportion			Proportion
	# of data	data	decluster	geological map	used
Gravel1	165	71.74	84.38	85.71	85.00
Gravel2	6	2.61	2.71	4.01	4.00
Gravel3	43	18.70	6.67	4.51	5.00
Sand	15	6.52	5.31	4.51	4.75
Silt	1	0.43	0.94	1.25	1.25

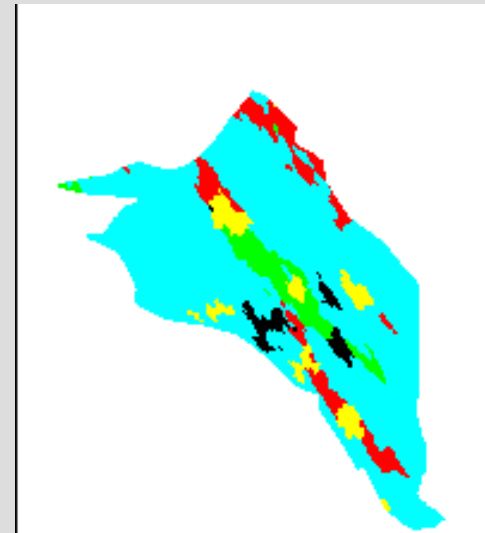
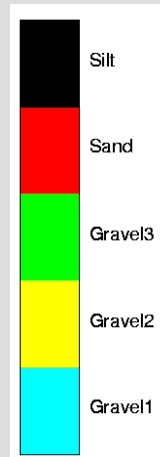
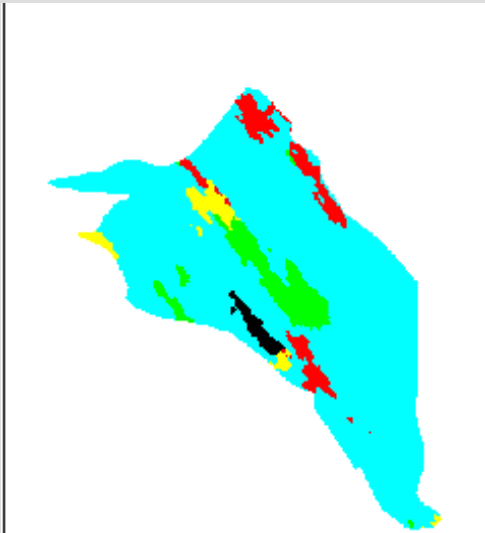
Facies 1 Indicator Variogram

- ▶ Variogram used to model spatial continuity of each facies
- ▶ Anisotropy accounts for greater continuity in direction of depositional flow

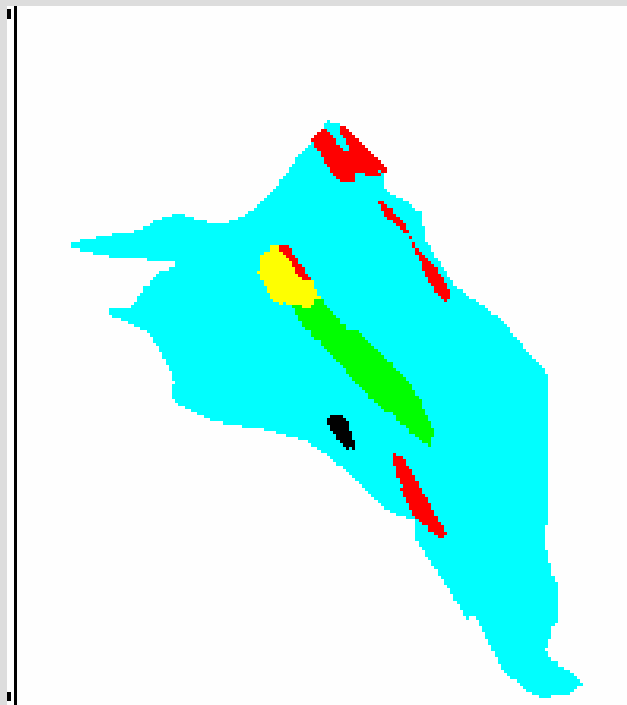


$$\gamma = 0.001 + 0.999 Sph \left(\begin{array}{cc} -35 & 55 \\ 16500 & 3000 \end{array} \right)$$

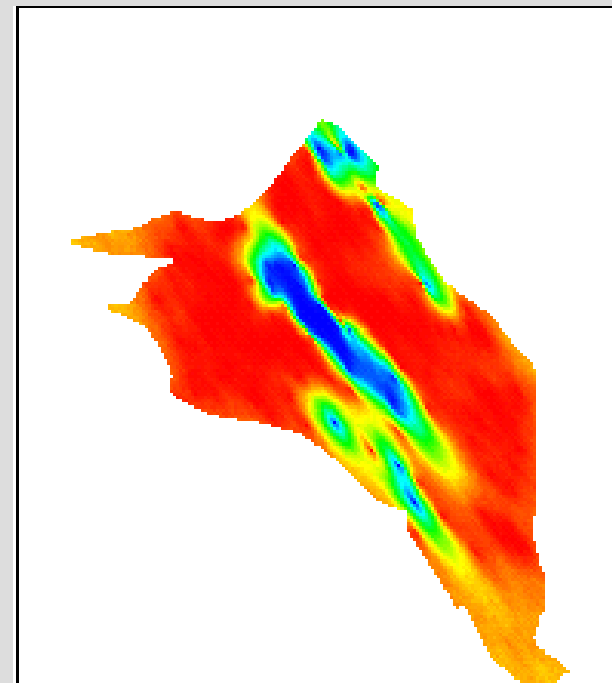
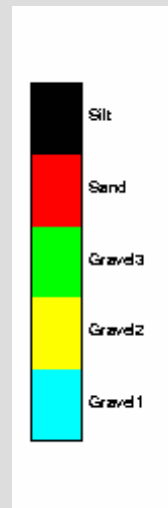
Example Realizations of U1 Facies Distribution



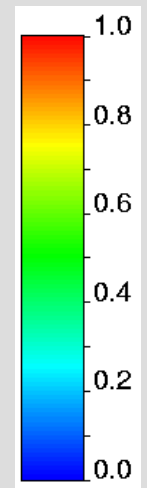
Representative Statistics from Suite of 600 Stochastic Simulations



Most Probable Facies



Probability of Gravel1



Ranking of Unit 1 Zonation Simulations

- ▶ Each grid node in each simulation
 - Assigned mean hydraulic conductivity associated with facies present at that node
- ▶ Simulations ranked based on connectiveness of high conductivity zones
- ▶ Will run suite of simulations with
 - Extremely low and high connectivity of high conductivity zones
 - Median connectivity ranking

Conclusions

- ▶ Geostatistics provides method of generating multiple alternative conceptual models of hydrogeology
 - Mean behavior of simulations similar to “best-fit” estimates of site geologist
 - Individual simulations capture variability seen in data – much more variable than “best-fit” model
- ▶ Forward and inverse modeling will allow estimation of uncertainty in contaminant transport due to uncertainty in hydrogeology